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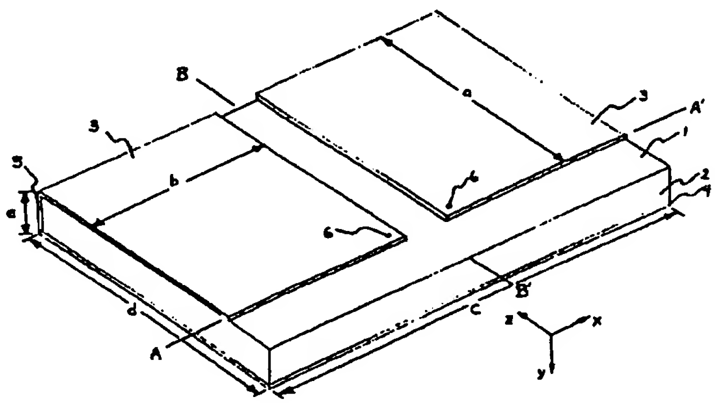
(54) ANTENNE FONCTIONNANT EN DIVERSITE EMETTANT DES SIGNAUX POLARISES

(54) POLARIZATION PATTERN DIVERSITY ANTENNA



(57) L'invention est une antenne à diversité de polarisation planar peu encombrante et facile à fabriquer dont le diagramme de rayonnement horizontal est approximativement équidirectif. Deux points d'alimentation fixés chacun à une plaque de cuivre fonctionnent en phase et en opposition de phase pour recevoir ou émettre deux composantes différentes d'un même signal. Ces plaques sont disposées symétriquement sur l'une des faces d'une couche diélectrique de façon à réduire le couplage RF entre les deux modes de fonctionnement, ce qui accroît le rendement énergétique et isole l'ensemble des ports d'entrée et de sortie pour les différentes composantes du signal. Le tapis de sol, qui se trouve sur la face de dessous de la couche diélectrique, permet à l'antenne de fonctionner comme une fente résonnante quand les points d'alimentation sont alimentés en phase. En fonctionnement en diversité, l'antenne peut réduire les évanouissements dus à la multiplicité des trajets qui est inhérente aux communications mobiles.

(57) A polarization pattern diversity antenna is described that is easy to manufacture, has a compact planar shape and radiates a nearly omnidirectional radiation pattern in the horizontal plane. Two feed points, each one attached to a copper patch, are operated in phase and 180° out of phase to separately receive or transmit two different components of a signal. The copper patches are arranged symmetrically on one side of a dielectric layer in such a way as to reduce the r.f coupling between the two modes of operation and thus increase the radiation efficiency and isolate the overall input/output ports for the different signal components. The ground plane, situated on the underside of the dielectric layer, allows the antenna to operate like a resonant slot when the feed points are excited in phase. Using diversity, the antenna can reduce the multipath fading effects inherent in mobile communications

Industrie Canada Industry Canada

Field of Invention

The present invention relates to antennas and, in particular, to antennas having a compact size and the ability to simultaneously receive or transmit two different components of electromagnetic energy.

Background

Microwave antennas are used in many forms of wireless communication where information is broadcast through the air between a transmitter and a receiver. The main advantage of broadcasting information is that it allows the transmitter and receiver to communicate without the need for both terminals to be connected to electrical wires at fixed locations. However, there are limits to the locations and motions of the terminals. These limits are imposed by different forms of signal loss that degrade the received signal — free-space loss, terrestrial loss, Doppler frequency shifting and multipath effects.

The multipath effects are the most significant form of loss at microwave frequencies and are particularly problematic in cellular telephony. Between the transmitter and receiver, components of the broadcast signal will travel along different paths, some of which may come across obstacles that scatter, refract, absorb, reflect or re-polarize them. In outdoor communication, these obstacles are typically trees, buildings, cars and the terrain. For indoor communications, they may be desks, people, walls and partitions.

Some of the signal components will arrive at their destination, but with different amplitudes, phases, polarizations and arrival times. Signal components with different phases may destructively interfere, resulting in signals partially or wholly canceling each other out. In addition, the polarizations of some of the signal components may be different from the polarization of the receive antenna, leading to further power loss.

The final received signal will have an amplitude and phase that are difficult to predict and will fluctuate in time with a multipath fading pattern as the receiver moves and the environment changes. Therefore, it is very difficult to ensure a clear, consistent signal at the receiver.

Deep fading of the signal as the receiver moves every half wavelength is inherent in broadcast communications and becomes a significant problem at

microwave frequencies, where a half wavelength is less than one metre. This problem could be overcome if the components from every signal path are separately received and then combined in such a way as to eliminate destructive interference. However, this task is impossible. A more practical approach is to separately receive two or more signals and combine them so that destructive interference is reduced. Each signal can be received by a separate antenna. Although the amplitude of each signal fluctuates with a multipath fading pattern, the combination of all signals fades less frequently. The greatest reduction in destructive interference is achieved when the signals have fading patterns that are statistically independent, or in other words, all the signals do not experience deep fades simultaneously.

Two or more antennas used in this way are collectively known as a diversity antenna. These antennas can be used in different ways to achieve different forms of diversity. Some of these forms of diversity are described by William C. Y. Lee in ***Mobile Communications Engineering***, New York: McGraw-Hill, 1982, pp. 273-289; they are: space diversity, frequency diversity, time diversity, pattern diversity and polarization diversity. Polarization diversity and pattern diversity are employed by the present invention because these forms of diversity enable a compact antenna structure to be designed without requiring any system level changes to the communications system.

In cellular telephony, diversity (mainly space diversity) has been used at the base stations for a number of years. However, at the portable communicator side, diversity reception has not been used because of the lack of compact and aesthetic inventions. Therefore, what is needed is an antenna that provides diversity in the receive frequency band of a portable communicator. The antenna must have a compact and planar shape so that it can conform to the shape of a vehicle or fit inside a portable communicator. It must also be built with a simple design and inexpensive materials so that it is easy to manufacture. Furthermore, the mutual coupling between the different modes of operation should be low to provide high radiation efficiency and high isolation between the overall input/output ports for the different signal components.

Most of the diversity antenna research to date has employed space diversity, which is impractical for use in hand held radios because the distance between the antennas is so large. There is, however, some important work in this area that concentrates on antenna designs with a flat profile.

Nishikawa et al. as disclosed in U.S. patent 5,146,232 issued on September 8, 1992 have designed two flat antennas — one a table antenna, the other resembling a folded F antenna — that operate in diversity when separated by more than 0.4 wavelengths. Although this design is too large for a handset, it can be mounted on a vehicle, replacing the traditional monopoles that can bend or break and may not be aesthetically pleasing.

K. Tsunekawa has created a working diversity system using two planar inverted-F antennas as described in his article *"Diversity Antennas for Portable Telephones," 39th IEEE Vehicular Technology Conference*, Vol. 1, May 1989, pp 50-56. By combining space and angle diversity, he was able to reduce the distance between the antennas to 0.1 wavelenth, but the antennas are only weakly independent.

Some important work in single, compact diversity antenna design is provided by Arai et al as disclosed in *"A Flat Energy Density Antenna System for Mobile Telephone," IEEE Transactions on Vehicular Technology*, Vol. 40, No. 2, May 1992, pp. 483-486. Their antenna consists of a center-fed disk above a ground plane with four slots cut radially into the disk. In the plane of this flat-profile antenna, the disk receives an electric field component while the slots receive a magnetic field component. Thus, field component diversity is achieved in one integrated unit. However, with a diameter of over 0.6 wavelength, this antenna is also impractical for use in a handset.

A simple polarization diversity scheme was taught by Lalezari et al over 10 years ago as disclosed in his U.S. patent 4,464,663 issued on August 7, 1984 wherein two feed line networks independently feed a pair of square microstrip patches. This system provides horizontal and vertical polarizations independently and is said to minimize the coupling between the feed ports, but again, size is a problem. To isolate the patches and make room for the two feed networks, the structure must be 0.95 wavelenth long.

Polarization diversity has been studied by a number of engineers, for example: Bergman and Arnold as described in *"Polarization Diversity in Portable Communications Environment," Electronics Letters*, Vol 22, No. 11, 1986; and W.C.Y. Lee reference previously. The results of these studies conclude that polarization diversity antenna offer substantial signal strength improvement over conventional antennas in most outdoor environments and in indoor systems where there is no direct line of sight between the fixed base station and the portable communicator. When there is a line of sight, diversity antennas perform only slightly better than a conventional monopole antenna. This is because only one polarization of the received signal (usually vertical) is dominant. In this case, however, the signal level is usually high and the multipath fading effects are not as severe.

Pattern diversity (or angle diversity) makes use of the observation that most of the components of a signal arriving from different paths also have different angles of arrival. In most mobile environments, the signal components from different angles of arrival will have fading patterns that are statistically independent. Therefore, diversity can be achieved if directional antennas are used to isolate these signal components. Research on pattern diversity shows that it offers an improvement in received signal strength over conventional antenna reception, particularly in environments where signals are arriving from many different angles. The directivities of the antennas must be chosen carefully, however; using highly directional antennas gives good statistical independence but less signal coverage area while using antennas with low directivity gives a broad signal coverage area at the expense of poorer statistical independence.

Summary of Invention

The invention herein is directed to a compact, polarization pattern diversity antenna that is designed with hand held cellular telephones in mind. This diversity system is capable of separately and simultaneously receiving both orthogonal polarizations (vertical and horizontal) of an incoming signal and/or components of a signal with different angles of arrival. Whether polarization

diversity or pattern diversity is the main scheme in use depends on the orientation of the antenna with respect to the incoming signals.

The invention herein employs a pair of conductive patches that are either implanted inside or layered on top of a dielectric material. The patches are rectangular in the preferred embodiment and separated by a narrow gap that resonates like a slot antenna, providing one of the two resonant modes. The other mode is provided by a second slot antenna, formed between the two patches and a conductive ground plane affixed beneath the dielectric.

The dimensions of the patches and how and where they are terminated are crucial to the operation of the diversity antenna. The back edges of both patches connect to the ground plane, creating a short circuit. This forces an open circuit along the front edges that are a quarter wavelength away at the resonant frequency. The two feed points are located near these front edges, on both sides of the gap between the two patches. When they are fed with signals of equal amplitude and opposite phase, currents form near the gap. These currents give rise to an electromagnetic field that radiates across the gap. The polarization of the field is in the direction orthogonal to that of the gap (hereafter referred to as the vertical polarization). When fed by signals of equal amplitude and equal phase, the feed points excite currents in the patch that, because of the open circuit condition, can only flow along the front edges of the two patches. Hence, an electric potential is established between these front edges and the ground plane resulting in an electromagnetic field that radiates from the structure with a polarization perpendicular to a line between the feed points (hereafter called the horizontal polarization).

The dielectric material is not essential to the operation of the antenna, but it provides mechanical stability and decreases the physical size. Materials with larger dielectric constants will decrease the size even further, but at the expense of concentrating the electromagnetic fields inside the material and thus preventing some radiation.

Using the dielectric material also allows the use of printed circuit technology in its fabrication, which has many advantages. The manufacturing process is inexpensive and accurate, making it readily amenable to mass production. Also,

this technology is compatible with integrated circuits, which can be mounted directly on the board, and feed lines and matching networks can be fabricated on the same dielectric. The light weight, compact size and planar geometry of the dielectric make it easy to use where small size is important or conformity with a structure is required. Microstrip antennas like this one are also rugged enough to withstand climatic changes and are essentially maintenance free.

Variations to the basic invention include embodiments where modifications have been made to any part of the antenna in order to change the physical or electrical properties without changing the basic operation of the antenna. Such modifications include but are not limited to cutting slots and/or holes of any shape into any of the conductive surfaces, carving wells into the dielectric, changing the positions of the feed points, tapering any of the conductive surfaces, tapering the dielectric, using dielectrics with non-homogeneous permittivities, curving or bending parts of or all of the embodiment, inserting grounding posts, adding matching circuits, filters or rectifiers, removing the dielectric, enclosing one or more surfaces of the embodiment with dielectric material, and using physical designs other than printed circuit technology.

Objects of Invention

The objects of the present invention are to provide an antenna that:

1. is easy to manufacture;
2. has a compact and planar shape so that it can conform to the shape of a vehicle or fit inside a portable telephone or other communicator;
3. receives or transmits two components of a signal separately and simultaneously. These two components are received using polarization diversity and/or pattern diversity. The motivation for this property is to reduce the multipath fading effects in mobile communications at high frequencies, but this property can also be used for other applications and in other systems;
4. minimizes the r.f. coupling between the two modes of operation so as to provide high radiation efficiency and high isolation between overall input/output ports for the different polarizations;
5. radiates each desired polarization nearly omnidirectionally in one plane of the antenna.

Brief Description of the Drawings

The above and further objects and advantages of the invention will be better understood by referring to the following description in conjunction with the accompanying drawings, in which:

FIG. 1 is a perspective view of a polarization/pattern diversity antenna constructed in acccordance with the invention.

FIG. 2 is a cross-sectional view of the antenna shown in FIG. 1 taken along cutting line A-A'.

FIG. 3 is a perspective view of the diversity antenna of FIG. 1 connected via matching circuits to a hybrid circuit, which may be used to separate the two components of the received signal.

FIG. 4 is a plan view of the back wall of the invention.

FIG. 5a is a graph of horizontal mode antenna radiation measurements of the vertical polarization in the YZ-plane of Figure 1.

FIG. 5b is a graph of horizontal mode antenna radiation measurements of the horizontal polarization in the YZ-plane of Figure 1.

FIG. 5c is a graph of vertical mode antenna radiation measurements of the vertical polarization in the YZ-plane of Figure 1.

FIG. 5d is a graph of vertical mode antenna radiation measurements of the horizontal polarization in the YZ-plane of Figure 1.

FIG. 6 is a perspective view of an alternate embodiment of a polarization/pattern diversity antenna constructed in accordance with the invention.

Description of Preferred Embodiment.

Referring now to Fig. 1 which depicts a perspective view of the invention, a polarization/pattern diversity antenna 1. The antenna 1 comprises a dielectric layer 2 which supports a pair of similar conductive patches 3 on one side and a continuous conductive layer 4 on the other, which serves as a ground plane. The patches 3 and the ground plane 4 are connected along the back by a conductive wall 5. This wall short circuits the back edge of each patch 3 to the ground plane 4 so that

they have zero voltage potential there.

The length a of the patches 3 is one quarter of a wavelength at the resonant frequency. From simple transmission line calculations, that makes the impedance equal to that of an open circuit along the front edges of the patches 3. Because of the dielectric layer 2, a wavelength is smaller than a free space wavelength by a factor equal to the inverse of the square root of the material's effective dielectric constant. Therefore, the dielectric layer 2 not only provides mechanical stability and durability but also makes the antenna more compact.

The width b of the patches 3 is not critical. It can be widened or narrowed to change the bandwidths or impedance matches. Accordingly, the total width c of the antenna 1 is also adjustable. Care should be taken to make the total width c and total length d of the antenna 1 as small as possible in an effort to make the structure as compact as possible without jeopardizing its operation. The size of the ground plane 4 (which does not have to be the same size of the antenna 1 as shown) is of particular importance. The smaller a ground plane is, the more it will lose its ideal properties and therefore the more the operation of the antenna 1 will be hampered.

The two feed points 6 of the antenna 1 are each located on its respective patch 3 near the front edge of the patch 3 and close to the line of symmetry B-B'. The positions of the feed points 6 are adjustable, however, they can be moved towards the back or to the outside to change the input impedances or any other parameter.

As stated earlier, the two modes of the antenna 1 are provided by exciting the feed points 6 in phase or 180° out of phase. When they are excited in phase, an electric field is created across a slot between the front edge of each patch 3 and the ground plane 4. Both sides of the gap between the patches 3 are at the same potential so an electric field cannot exist across it. There is therefore little coupling between the electric field from the patches 3 to the ground plane 4 and the electric

field across the gap.

When the feed points 6 are excited out of phase, the potential across the gap creates an electric field whose polarization is orthogonal to the electric field between the patch 3 and ground 4. The electric potential on one side of the gap is different from ground and therefore an electric field can be created between that side and the ground plane 4, but because an equal and opposite potential exists on the other side of the gap, the two fields cancel each other out. Therefore, the antenna 1 has inherent isolation between its two modes of operation.

A cross-sectional view of the antenna 1 through the xy plane containing A-A' is given in Fig. 2. In the preferred embodiment the feed points 6 are connected to feed connectors 7a and 7b via feed posts 8 through the dielectric material 2 and the ground plane 4. In this particular embodiment, the feed connectors 7a and 7b may be screwed or soldered onto the ground plane 4. In a minor variation to this embodiment, matching circuits, filters or other circuits are connected between the feed posts 8 and the feed connectors 7a and 7b. It is not necessary that the antenna 1 is fed through the dielectric 2 and the ground plane 4. The antenna 1 could be fed from the top. However, the former method is preferred as the feed connectors 7a and 7b and any connecting circuits are out of the way of the radiating fields. Referring to Fig. 3, there is illustrated in a perspective view, the diversity antenna of Fig. 1 connected via matching circuits to a hybrid circuit.

To separate the two components of the received signal (which will have different polarizations and/or different angles of arrival, depending on the orientation of the antenna), a hybrid circuit may be used. This hybrid circuit splits and then combines the signals form the feed connectors 7a and 7b with different phases to create the two components out the left hand side.

Fig. 4 is a view of the back wall 5 of the antenna 1. In the main embodiment, the wall 5 is a continuous conductive surface, although it

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could just as easily be a series of conductive posts or a conductive mesh (this also applies to the ground plane 4 and the conductive patches 3). The dotted line 9 illustrates one method of reducing the resonant frequencies without increasing the length a of the patches 3. By cutting out the area bordered by the dotted line 9, the gap between the two patches 3 is lengthened by an amount f, or, put another way, the length a is now reduced by an amount f.

The height e of the dielectric layer 2 is variable. Thicker dielectrics will increase the bandwidth of the horizontally-polarized signal and may reduce the length a of the patches 3 (if the method just described is used) but will make the antenna bulky in the y direction.

Measured radiation patterns of one version of the invention are given for the horizontal (yz) plane in Fig. 5. This is the plane where polarization diversity exists. Figs. 5a and 5b show the vertically-polarized and horizontally-polarized radiation, respectively, when the antenna is in horizontal mode. The horizontal polarization is strong and nearly omnidirectional while the vertical polarization is much weaker. On average, the horizontal polarization is 23.6 dB stronger than the vertical. A similar situation is found when the antenna is in vertical mode (as shown in Figs. 5c and 5d). The vertical polarization is strong and fairly close to omnidirectional in the horizontal (yz) plane while the horizontal polarization is 19.9 dB weaker on average.

In the xy and xz planes, this version of the invention exhibits pattern diversity.

Referring to FIG. 6, there is shown an alternate embodiment of a polarization/pattern diversity antenna, generally indicated by the reference numeral 11. This embodiment has a structure that is identical to that of antenna 1 of the previous embodiment, except that the dielectric layer 2 has been removed, leaving only air 12 to serve as a dielectric. Additionally, the elements of this embodiment are dimensioned on a larger scale than the corresponding elements of the

previous embodiment. Specifically, and except as to scale, conductive patches 13, a continuous conductive layer 14, a conductive wall 15 and feed points 16, of this embodiment are configured in an identical manner to the conductive patches 3, the continuous conductive layer 4, the conductive wall 5 and the feed points 16 of the previous embodiment, respectively.

As was mentioned above, use of a dielectric layer results in a wavelength that is smaller than a free space wavelength by a factor equal to the inverse of the square root of the material's effective dielectric constant. Use, in this embodiment, of air, only as the dielectric, therefore results in a larger wavelength, and the need for a correspondingly larger antenna 11.

The functionality of the antenna 11, of this embodiment, is identical to the functionality of the antenna 1 of the previous embodiment.

What is claimed is:

1. A polarization/pattern diversity antenna capable of simultaneously receiving or transmitting two different components of electromagnetic energy, said diversity antenna comprising:

a dielectric layer having an edge and first and second faces;

a pair or rectangular conductive patches, each having a length of one quarter of a wave length and a predetermined width, disposed on the first face in spaced relation defining a gap therebetween;

a ground plane disposed on the second face;

a conductive wall disposed on the edge and connecting the pair of rectangular conductive patches to the ground plane; and

two feed points, each one positioned on a respective conductive patch remote from the conductive wall and adjacent the gap.

2. The polarization/pattern diversity antenna of claim 1 wherein the feed points are connected to feed connectors through the dielectric layer and the ground plane.

3. The polarization/pattern diversity antenna of claim 1 wherein the feed points are connected to feed connectors on top of the antenna.

4. The polarization/pattern diversity antenna of claim 2 or 3 wherein matching circuits are placed between the feed points and the feed connectors.

5. The polarization/pattern diversity antenna of claim 4 wherein the feed connectors are connected to a hybrid circuit to achieve the in phase and 180° out of phase signaling.

6. The polarization/pattern diversity antenna of claim 5 wherein

the feed points are moved from their respective positions near the front inside corners of said conductive patch in such a way that does not change the basic operation of the antenna.

7. The polarization/pattern diversity antenna of claim 6 wherein the dielectric layer has a non-homogeneous permittivity.

8. The polarization/pattern diversity antenna of claim 7 wherein dielectric material surrounds at least one surfaces of the antenna.

9. The polarization/pattern diversity antenna of claim 8 wherein posts are inserted between the patches and the ground plane.

10. The polarization/pattern diversity antenna of claim 9 wherein the antenna comprises be printed circuit technology.

11. The polarization/pattern diversity antenna of claim 6 wherein the dielectric layer is air.

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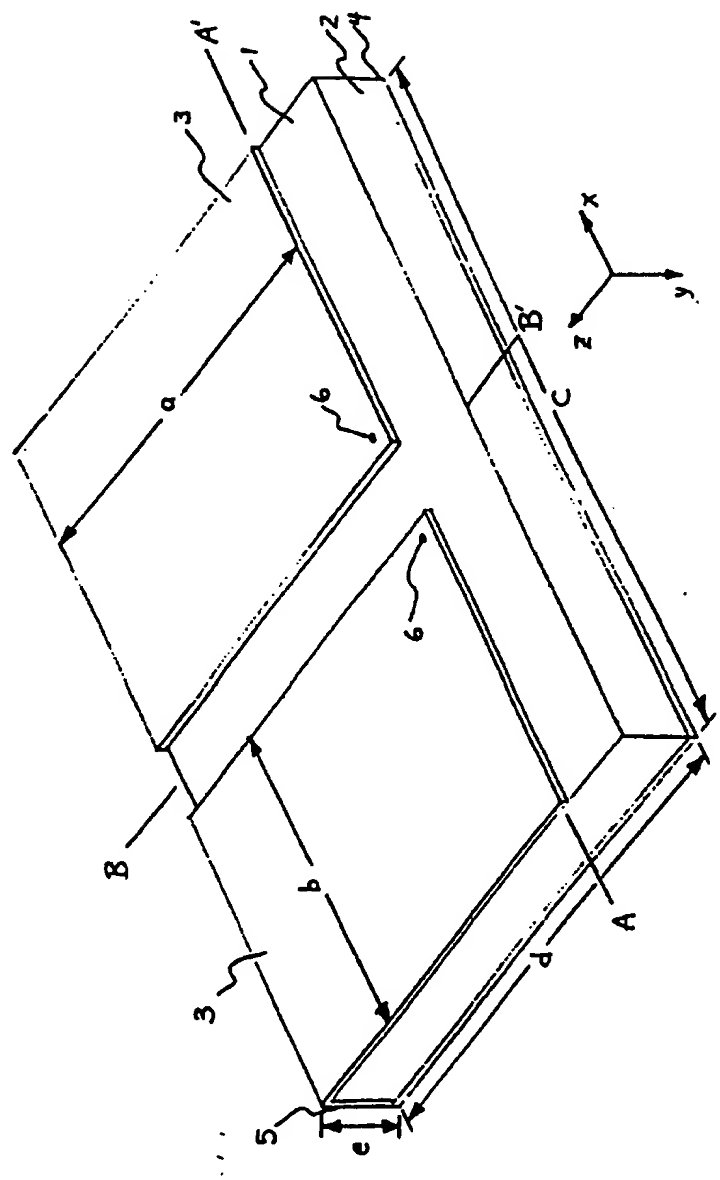

Fig. 1

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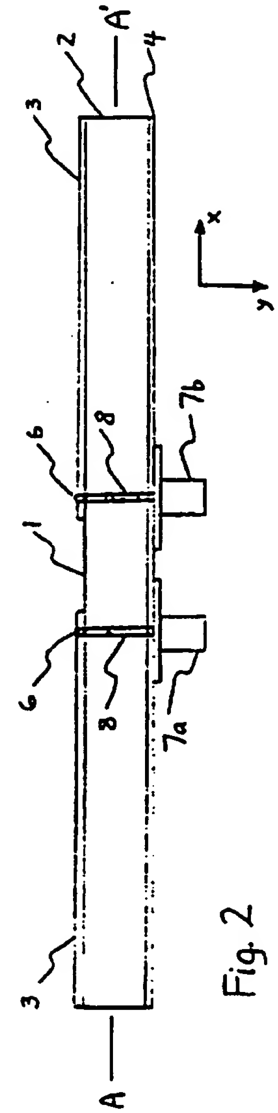

Fig. 2

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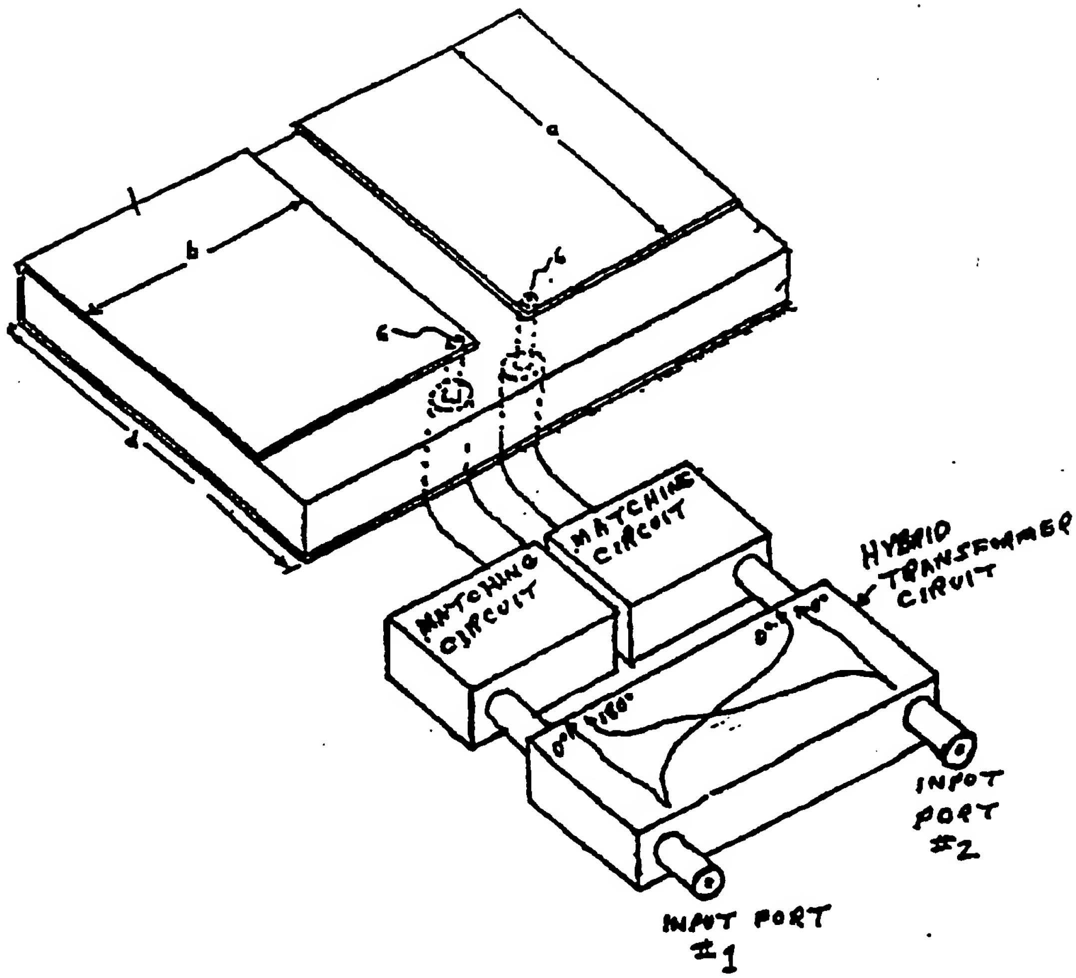

Fig. 3

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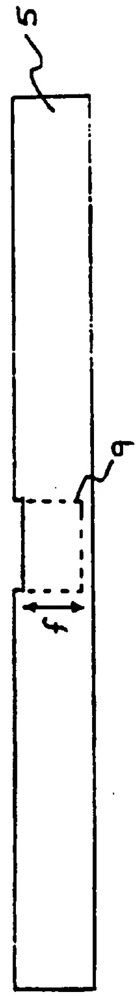

Fig 4

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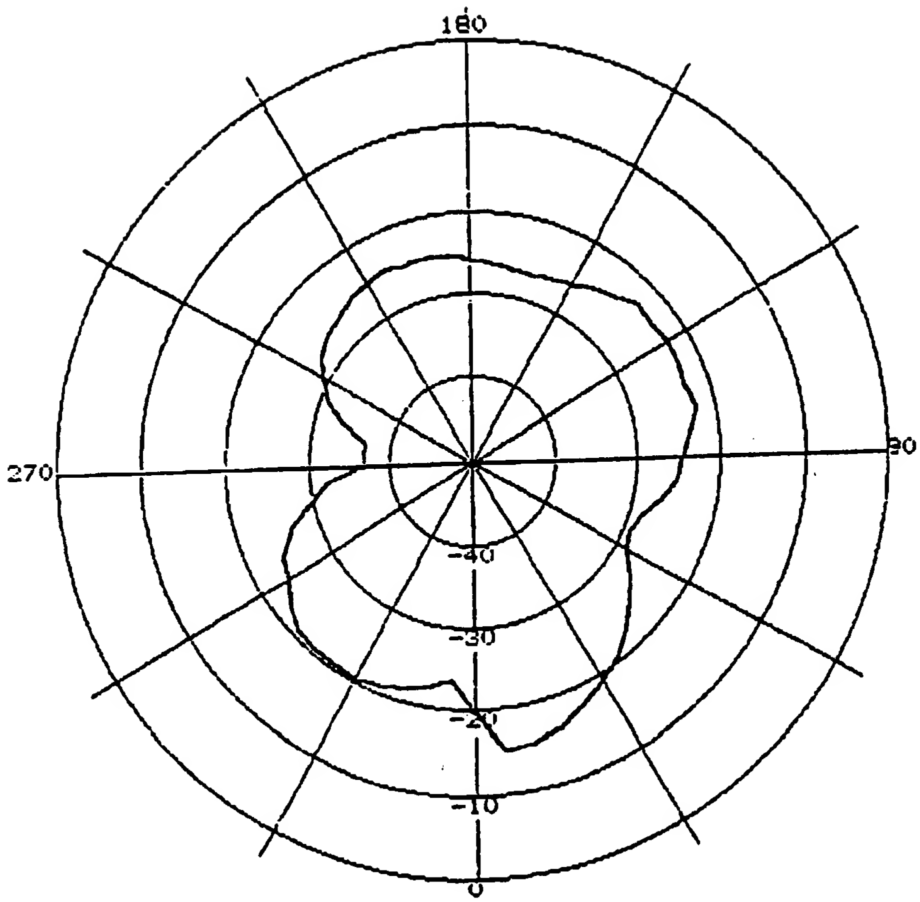

Fig. 5a

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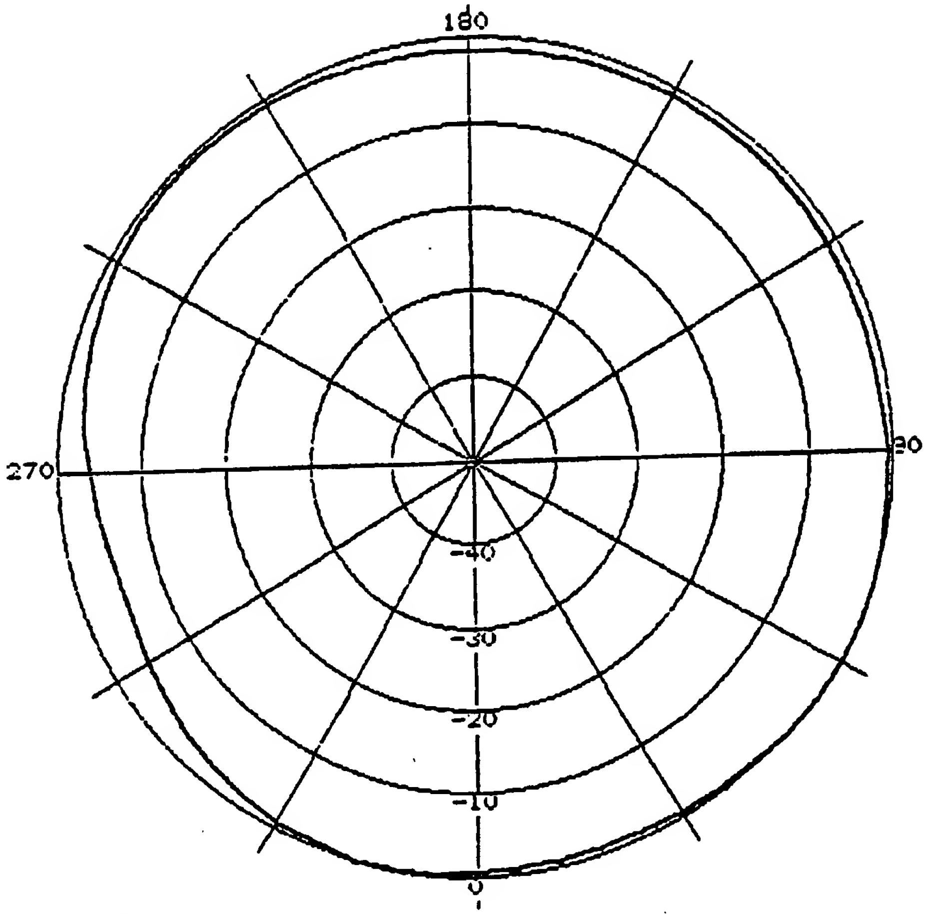

Fig. 5b

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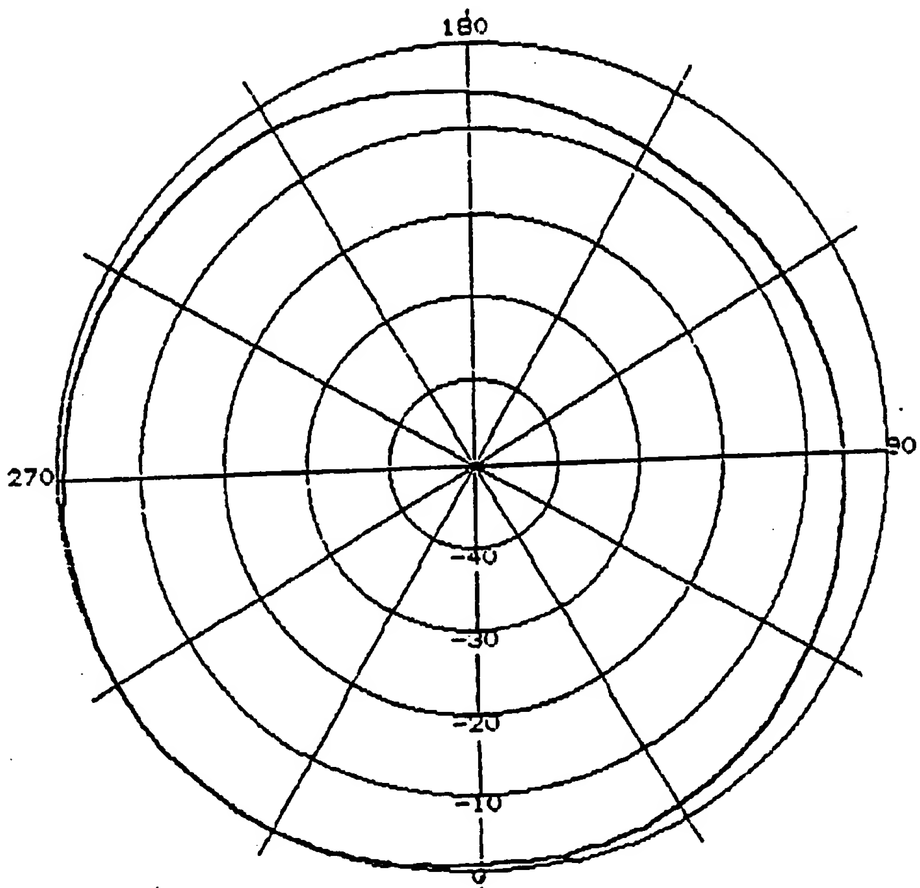

Fig. 5c

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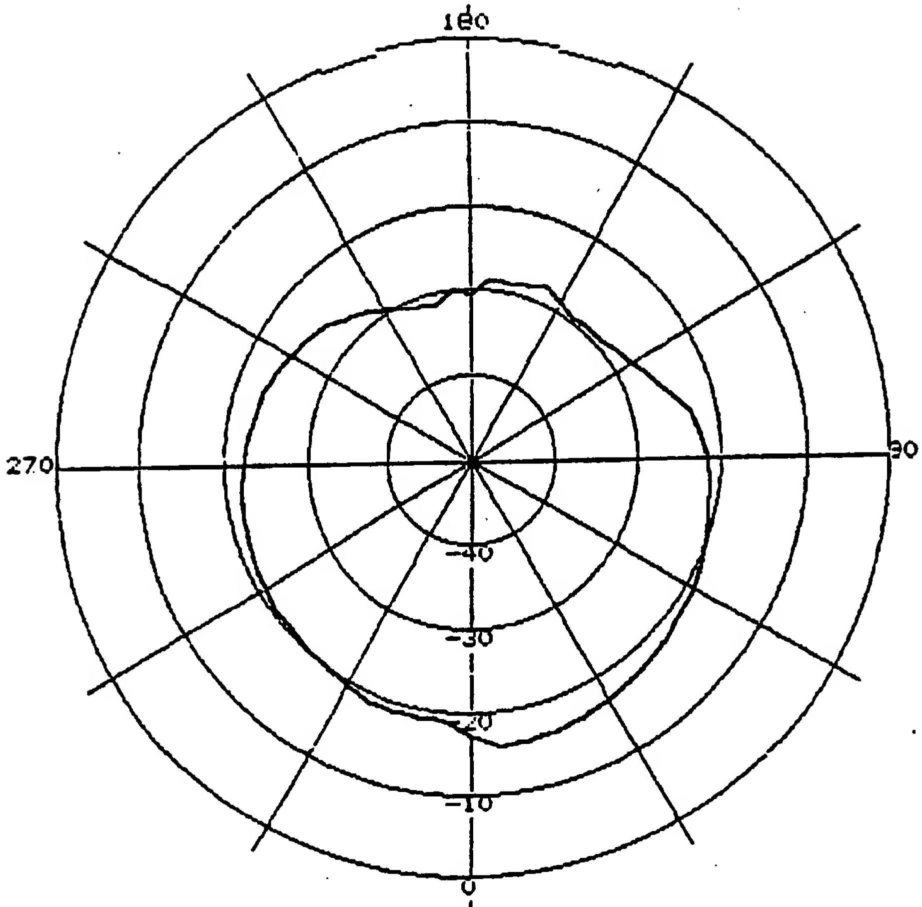

Fig 5d

Gallop, Dolby & Henderson

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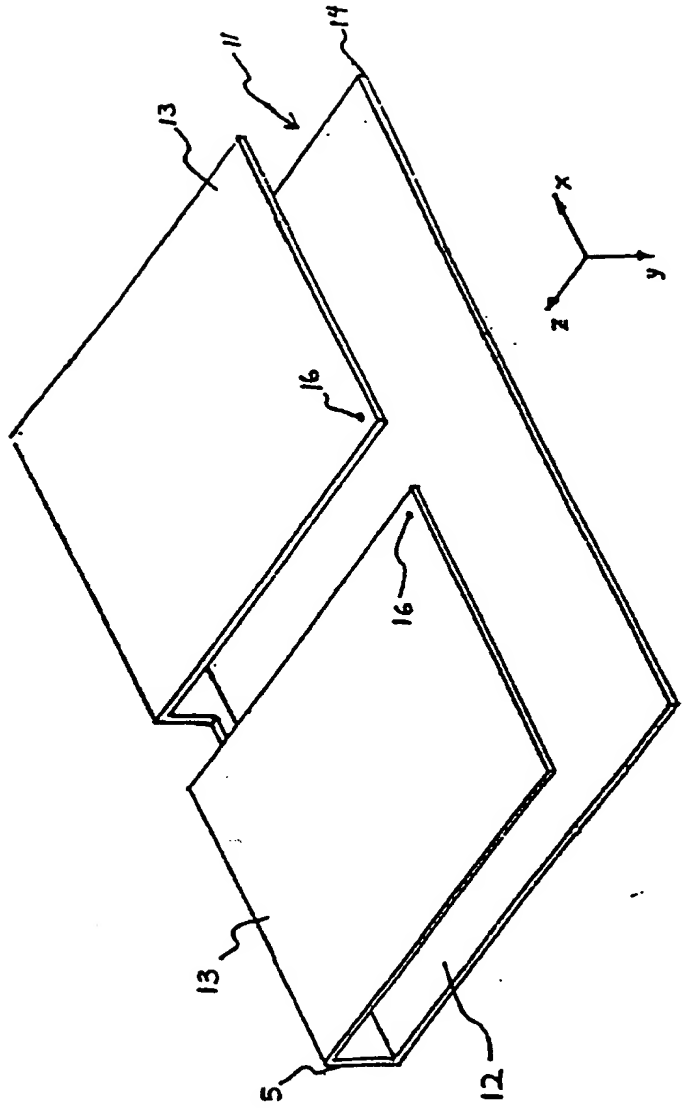

Fig. 6

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